

**Is the ozone hole getting smaller? How much rain is in the cloud of a hurricane? How do forest fires and volcanoes impact air quality around the globe? Compelling questions like these are driving NASA scientists and engineers to answer them for the benefit of people everywhere. Engineers and scientists are essential partners in this process.**

Engineers design instruments to measure energy across the electromagnetic spectrum. This energy travels in waves and these waves behave in predictable ways. They can be reflected, absorbed, scattered, and transmitted. Instruments measure how these waves behave when they interact with matter such as the Earth's surface or particles in the atmosphere. Scientists use this information to answer questions about the physical and chemical composition of our planet.

Some instruments are passive in that they sense energy emitted from the Earth's surface or solar energy reflected off the surface of the Earth. Mappers, or imaging instruments, measure light reflecting off the surface of the Earth to create images somewhat like an image from a digital camera. Sounders measure the vertical structure of the atmosphere either by observing the edge of the atmosphere (limb) or measuring the absorption of radiation vertically. These passive instruments use spectrometers to break apart and measure multiple bands of the spectrum like a prism, or use radiometers with filters to measure a specific band of energy.

Other instruments actively send infrared light or microwave pulses toward the Earth surface. Scientists can determine the heights of features on the Earth's surface such as mountains, sea level, and ice sheets by measuring the amount of time it takes for the signal to return. Scientists can also learn about the composition of the atmosphere by

measuring how that signal interacts with the atmosphere as it returns to the instrument. Lidar and Radar are examples of active instruments.

Just as you can use data from a thermometer, barometer, and a hygrometer to get a clearer picture of the weather outside, scientists use a variety of instruments to get the bigger picture of our Earth system. Since one satellite can only carry a few of these instruments each, multiple satellites are used to collect data over the entire globe every day.

In 2004, NASA launched the Aura satellite to study the chemistry of the Earth's atmosphere. The instruments on-board Aura are helping scientists study air quality, the changing size of the ozone hole, and links between ozone chemistry and climate.

Aura is just one in a constellation of polar-orbiting satellites and together they collect data about the atmosphere, ocean, land, ice, and snow, and their influence on climate and weather. Data from these instruments are helping improve weather forecasts, manage agriculture and forests, inform fishermen and local planners, and expand our understanding how the Earth's climate is changing.

For printable worksheets, materials list, and more resources, visit the Aura mission website:  
<http://aura.gsfc.nasa.gov/outreach>

# Satellite Subsystems

All spacecraft require systems to operate properly. From capturing and storing energy to transmitting data, these systems are essential to a successful satellite mission and its contribution to science.

**Attitude Control**      **150 Watts**  
The attitude control subsystem calculates the satellite's orientation with respect to the Earth and generates information necessary for adjusting the orbit and attitude of the satellite.

**Communications**      **100 Watts**  
The receiving antenna, the main component of the communications subsystem, receives instructions from scientists on the ground. Scientists typically send 2 signals to the satellite per orbit, which require 50 Watts of power for each reception.

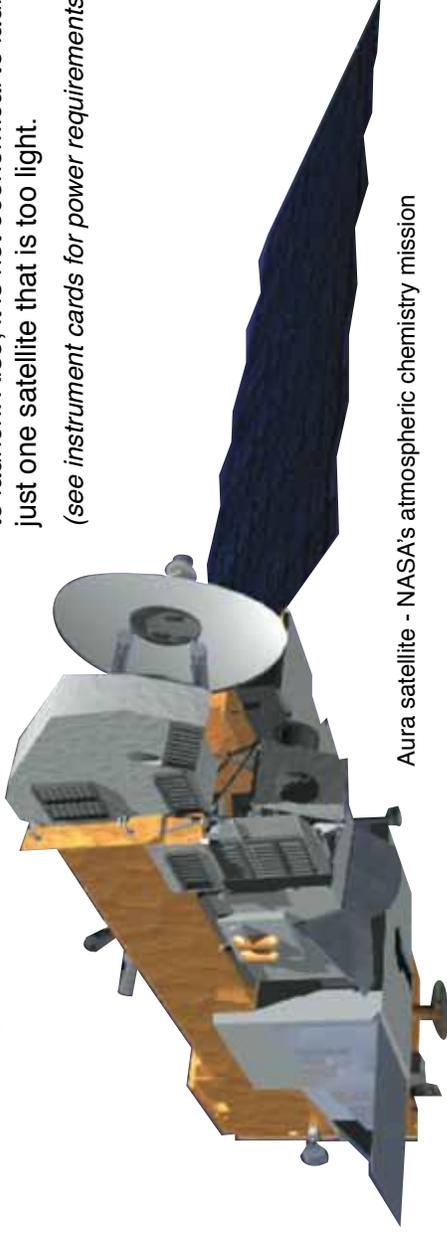
**Data Handling**      **200 Watts**  
The data handling subsystem handles the recording and transmission of the data collected by the instruments. Power is required to playback the data for transmitting to the ground station via X-band microwave frequency.

**Thermal Control**      **75 Watts**  
The thermal control subsystem maintains the temperature on board the satellite. Typical components include temperature sensors, thermostats, control electronics, and heaters - together requiring 75 Watts of power per orbit. Additional components such as fixed radiators, louvers, multi-layer blankets, coatings, and tapes are used to control for the effects of heat from both the Sun and the Earth's reflected sunlight.

**Propulsion**      **25 Watts**  
The propulsion subsystem generates the thrust necessary for adjusting the orbit and attitude of the satellite. Small mono-propellant rockets give the spacecraft the capability to adjust its orbit periodically to compensate for the effects of atmospheric drag, so that the orbit can be precisely controlled to maintain altitude and the assigned ground track.

**Instrument subsystem**  
The instrument subsystem contains all the sensors used to gather information about the Earth. This subsystem also includes a computer and calibration instruments.  
The number of instruments on a satellite is critical to both its purpose and its design. Having too many instruments on one satellite can cause problems such as being too heavy to launch. Also, it is not economical to launch just one satellite that is too light.

(see *instrument cards for power requirements*)



Aura satellite - NASA's atmospheric chemistry mission

## Electrical Power subsystem

This subsystem generates and distributes the electrical power required for operating the satellite. Determine the size of the solar array and battery after calculating your satellite's total power requirements.

**Batteries** store energy to power the satellite for half of each orbit where the satellite is not exposed to the sun.

The **solar array** is a collection of solar panels that work together to convert energy from the sun to power the satellite. A solar array must generate two times the total power required. This enables the array to not only power the satellite half the time, but also recharge the batteries.

### **Sounding Spectrometer**

**Power: 250 Watts**

**Mass: 175 kg**



The Atmospheric Infrared Sounder (AIRS) instrument on board the Aqua satellite, takes measurements of the gases in our atmosphere at different heights. The information from AIRS helps scientists learn more about our weather and climate.

The image on this card shows the distribution of water vapor in the atmosphere. Water vapor at higher altitudes appears brighter.

<http://airs.jpl.nasa.gov/>  
<http://aqua.nasa.gov>

### **Imaging Spectrometer**

**Power: 100 Watts**

**Mass: 50 kg**



The Ozone Monitoring Instrument (OMI) spectrometer onboard the Aura satellite measures ultraviolet and visible light to measure particles and gases in the atmosphere and to track pollution near the Earth's surface.

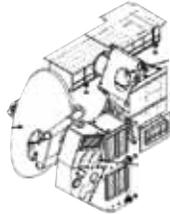
The image on this card shows OMI data of ozone in the stratosphere for October of 2010. These data help scientists monitor the changes in the ozone hole above Antarctica.

<http://ozonewatch.gsfc.nasa.gov/>  
<http://aura.gsfc.nasa.gov/>

### **Sounding Spectroradiometer**

**Power: 550 Watts**

**Mass: 450 kg**



The Microwave Limb Sounder (MLS) instrument onboard the Aura satellite measures five different bands in the microwave region of the electromagnetic spectrum. This microwave radiometer has a unique ability to measure the presence and vertical distribution of gases in our atmosphere.

The image on this card shows ozone (left) and chlorine monoxide (right) over the Arctic.

<http://aura.gsfc.nasa.gov/>

### **Imaging Spectroradiometer**

**Power: 250 Watts**

**Mass: 225 kg**



The Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Aqua and Terra satellites measures visible and infrared energy. This instrument can provide images similar to what our eyes can see of the Earth's surface.

The image on this card shows the distribution of vegetation and ice in North America.

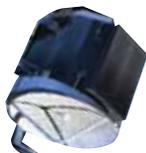
<http://modis.gsfc.nasa.gov/>

### **Radar**

**Power: 300 Watts**

**Mass: 250 kg**

**Antenna diameter: 1.85m**



The Cloud Profiling Radar (CPR) instrument on the Cloudsat satellite uses microwave pulses at 94-GHz to determine the structure of clouds and the amount of liquid water or ice water in the clouds.

The image on this card shows a storm cloud. The more water in the cloud, the stronger the reflected signal. The red colors in this image show more water content.

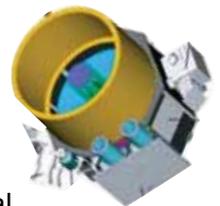
<http://cloudsat.atmos.colostate.edu/>

### **Lidar**

**Power: 250 Watts**

**Mass: 150 kg**

**Telescope diameter: 1m**



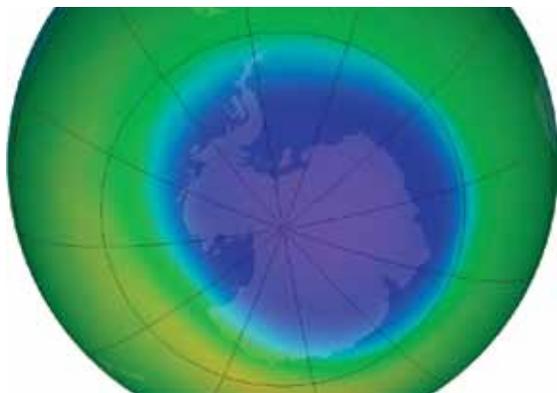
Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) can measure the distribution of aerosols and clouds over the globe by measuring how water vapor, ice and other particles scatter light differently.

The image on this card shows how the plume from a volcanic eruption in Iceland traveled over Europe. This event caused delays of flights in and around Europe in 2010.

<http://www-calipso.larc.nasa.gov/outreach/>

### Imaging Spectrometer

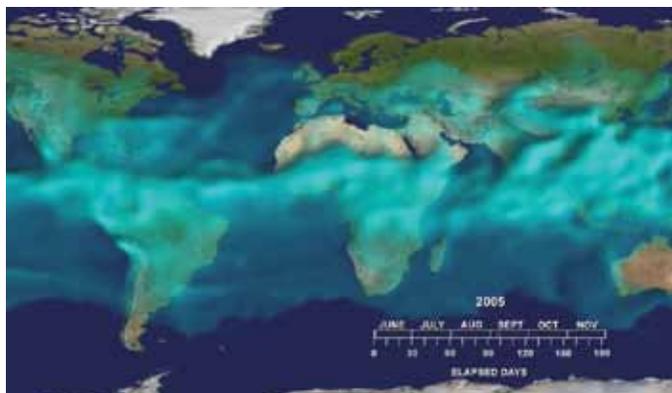
100 Watts



An imaging spectrometer uses diffraction to separate light into a range of wavelengths to create images, or maps, of the Earth's surface or atmosphere.

### Sounding Spectrometer

250 Watts



A sounder can take measurements at different levels of the atmosphere to determine the vertical distribution of gases such as water vapor.

### Imaging Spectroradiometer

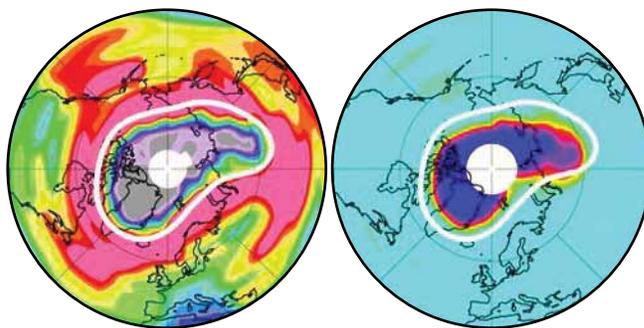
250 Watts



An imaging spectroradiometer creates images using different filters to isolate and measure energy within specific bands of energy.

### Sounding Spectroradiometer

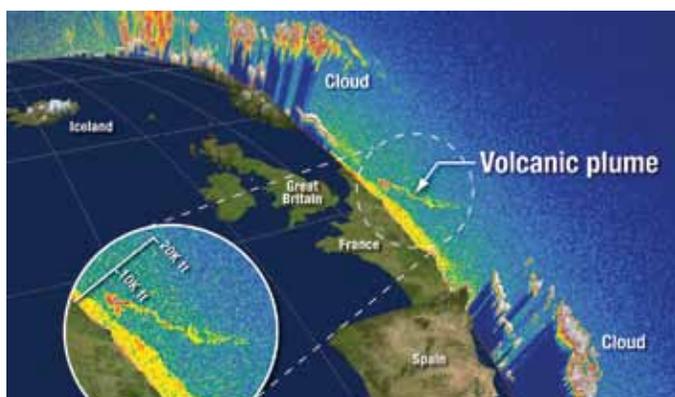
550 Watts



A sounder spectroradiometer can take measurements from different levels of the atmosphere using filters to isolate specific bands of energy.

### Lidar

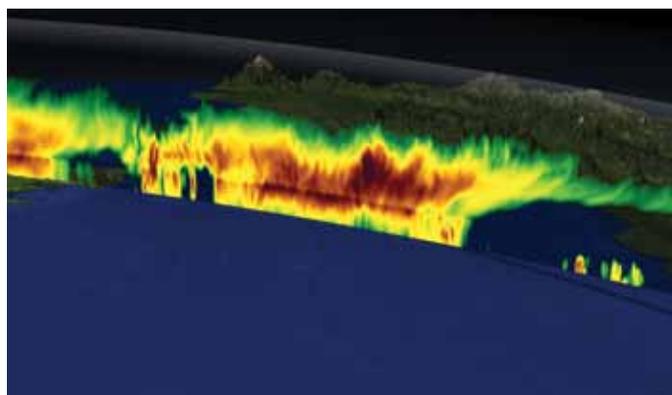
250 Watts



Lidar sends infrared light pulses and measures the reflection and scattering to image the distribution of aerosols and gases in the atmosphere.

### Radar

300 Watts



Radar actively sends microwave pulses and measures the reflection and scatter behavior of the energy returned.

# Engineer a Satellite

1

## PICK YOUR INSTRUMENTS

What would you like your satellite to observe about the Earth system?

Review the different types of instruments used for Earth observation and select up to 3 instruments you want onboard your satellite.

- |  |  |
|--|--|
| <input type="checkbox"/> Imaging Spectrometer      | <input type="checkbox"/> Sounder Spectrometer      |
| <input type="checkbox"/> Imaging Spectroradiometer | <input type="checkbox"/> Sounder Spectroradiometer |
| <input type="checkbox"/> Lidar                     | <input type="checkbox"/> Radar                     |

## CALCULATE POWER REQUIREMENTS

2a

### Calculate the total power required for all subsystems and instruments:

Every satellite needs systems to operate and maintain the satellite. Record the power required for each subsystem and instrument you choose. Total the power required.

**Attitude Control subsystem** Power \_\_\_\_\_

**Communications subsystem** Power \_\_\_\_\_

**Data Handling subsystem** Power \_\_\_\_\_

**Thermal Control subsystem** Power \_\_\_\_\_

**Propulsion subsystem** Power \_\_\_\_\_

**Instrument Package:** 1: \_\_\_\_\_ Power \_\_\_\_\_

Up to 3 instruments  
you selected above

2: \_\_\_\_\_ Power \_\_\_\_\_

3: \_\_\_\_\_ Power \_\_\_\_\_

Total power required for all subsystems and instruments:

2b

### Calculate the Electrical Power subsystem:

The solar array must generate twice the total power required to power the satellite and recharge the batteries for half of each orbit when the satellite is exposed to the sun.

**Round answers up to the nearest whole number.**

**Solar Array:** 1 solar array = 2400 Watts of power generated

Total power  x2  / 2400 =  arrays needed.

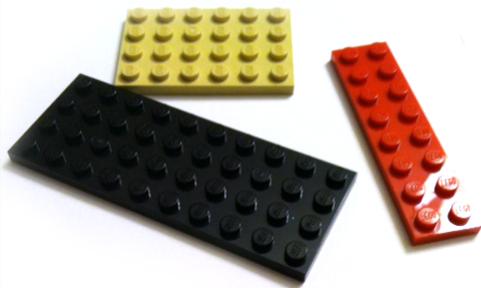
**Battery:** 1 cube = 300 Watts of power stored

Total power  / 300 =  batteries needed

## MATERIALS

**3a**

Collect one of each subsystem:



Satellite bus - platform where all subsystems are mounted

Propulsion



Attitude Control



x-band antenna



Data Handling

Thermal Control



s-band antenna

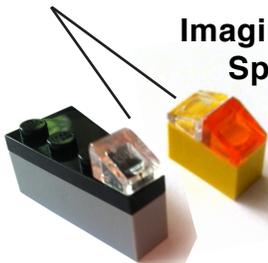


Communications

**3b**

Select instruments:

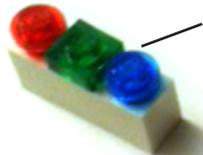
Spectrometers diffract energy similar to how a prism separates white light into a rainbow



Imaging Spectrometer

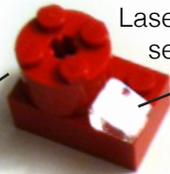
Sounder Spectrometer

Imaging Spectroradiometer



Filters isolate specific wavelengths of energy

Lidar



Optics to measure returned pulses

Laser to actively send pulses

Radar



Antenna to sense microwave pulses

Sounder Spectroradiometer



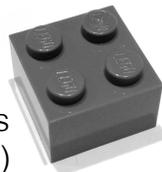
Reflector focuses Earth-emitted microwave radiation

**3c**

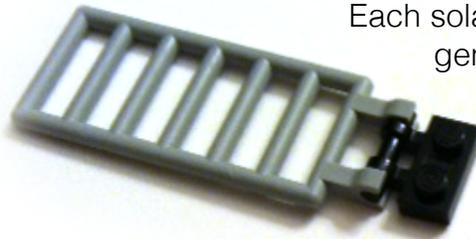
Collect batteries & Solar arrays (use calculation from 2b):



1x1 brick = 1 battery  
(300 Watts of power)



2x2 brick = 4 batteries  
(1200 Watts of power)



Each solar array can generate up to 2400 Watts of power.

**4**

**BUILD** - Assemble all subsystems on to the platform

**5**

**ARE YOU READY FOR LAUNCH?**

Weigh your satellite. If it is between 14g and 25g, congratulations, you're ready to launch!

# Engineer a Satellite

Select the scientific instruments for your satellite, calculate the power requirements for all the subsystems, and construct a scale model of your very own Earth observing satellite.

## 1 PICK YOUR INSTRUMENTS:

What would you like your satellite to observe about the Earth system? Review the instrument cards and select up to 3 instruments you would like onboard your satellite.

## CALCULATE POWER REQUIREMENTS

### 2a Record and total the amount of power required for all subsystems:

Every satellite needs systems to operate and maintain the satellite. Record the power required for each subsystem and instrument you choose. Total the power required.

**Attitude Control subsystem** Power \_\_\_\_\_

**Communications subsystem** Power \_\_\_\_\_

**Data Handling subsystem** Power \_\_\_\_\_

**Thermal Control subsystem** Power \_\_\_\_\_

**Propulsion subsystem** Power \_\_\_\_\_

**Instrument Package (select up to 3)**

1: \_\_\_\_\_ Power \_\_\_\_\_

2: \_\_\_\_\_ Power \_\_\_\_\_

3: \_\_\_\_\_ Power \_\_\_\_\_

**Total power required for all subsystems and instruments:**

### 2b Calculate the Electrical Power subsystem:

The solar array must generate twice the total power required to power the satellite and recharge the batteries for half of each orbit where the satellite is exposed to the sun.

**Solar Array:** 1 cm<sup>2</sup> of solar array on your model = 50 Watts of power generated

Total power  x2 =  / 50 =  cm<sup>2</sup> of solar array needed.

**Battery:** 1 cube = 800 Watts of power stored

Total power  / 800 =  battery cubes needed.

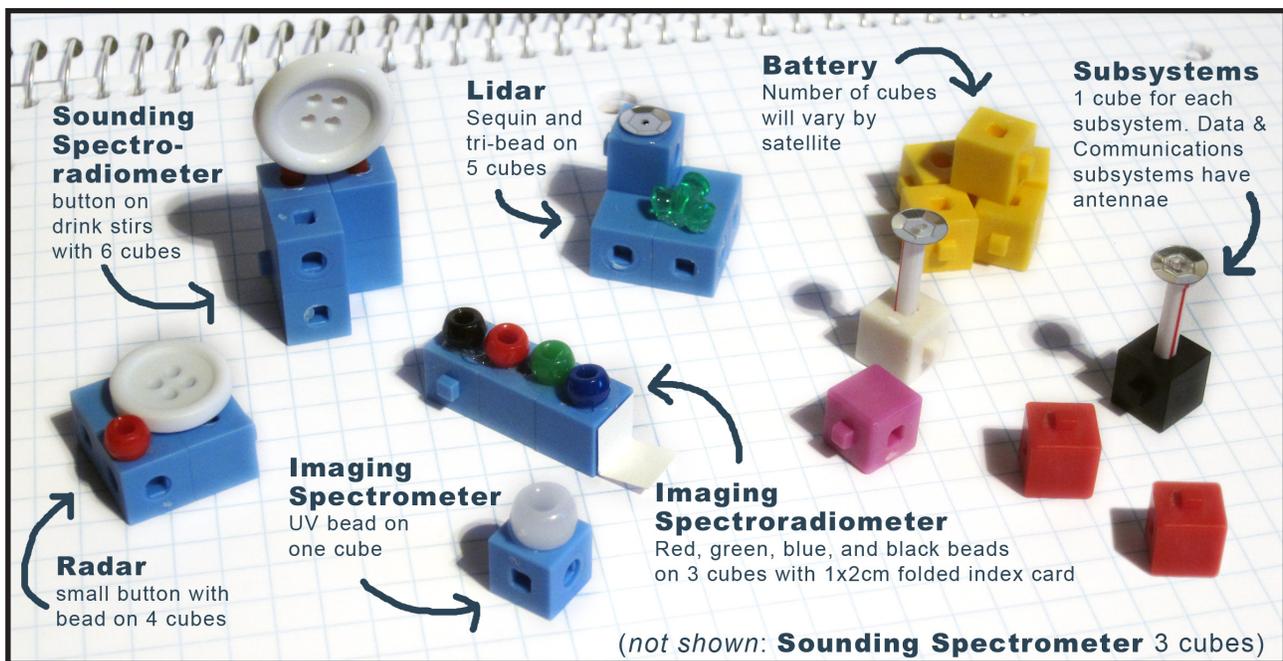
### 3a Collect supplies for your scale model:

- 2 drink stirrs (about 3mm in diameter)
- 3 sequins
- 2 buttons: 1 large (2cm) and 1 smaller
- 7 beads: 2 Red, 1 Green, 1 Blue, 1 Black, 1 UV sensitive, and a Triangle-bead
- 10 cm square of blue paper
- 27 interlocking gram centimeter cubes - (15 of one color for the instruments, 8 of one color for the batteries, 5 for the subsystems)
- 3cm x 10cm piece of cardboard or foamcore
- Scissors, ruler, tape, glue or Glue Dots

### 3b Construct your satellite:

Construct the instruments by attaching beads, buttons, sequins, and drink stirrs to the cubes using Glue Dots (see photo below). The communications and data handling subsystems each require an antenna (short drink stir with sequin).

Use the information on the worksheet to calculate to required solar array size and number of batteries. The cardboard will serve as the satellite bus - the platform to which all the subsystems are attached. Construct the satellite by connecting all the cubes and attaching to the cardboard with glue dots. Finally, tape the solar panels to drink stirrs and connect to any cube.



### 4 Are you Ready for Launch?

Weigh your satellite. If your satellite weighs between 18 and 25 grams, congratulations! Your satellite is ready to launch!

### 5 Go further!

1. Name your new satellite and describe how the data from the instruments will help benefit society.
2. Learn more about the electromagnetic spectrum and Earth observing satellites at:
  - Aura mission: <http://aura.gsfc.nasa.gov/outreach/>